CHAPTER FOUR

Bipolar Digital Circuits

Digital Electronics.

Introduction

- This chapter describes:
  - Basic types of logic circuits:
    1. D-R-L
    2. BJT inverter
    3. T-T-L

Terminal Currents and Voltages

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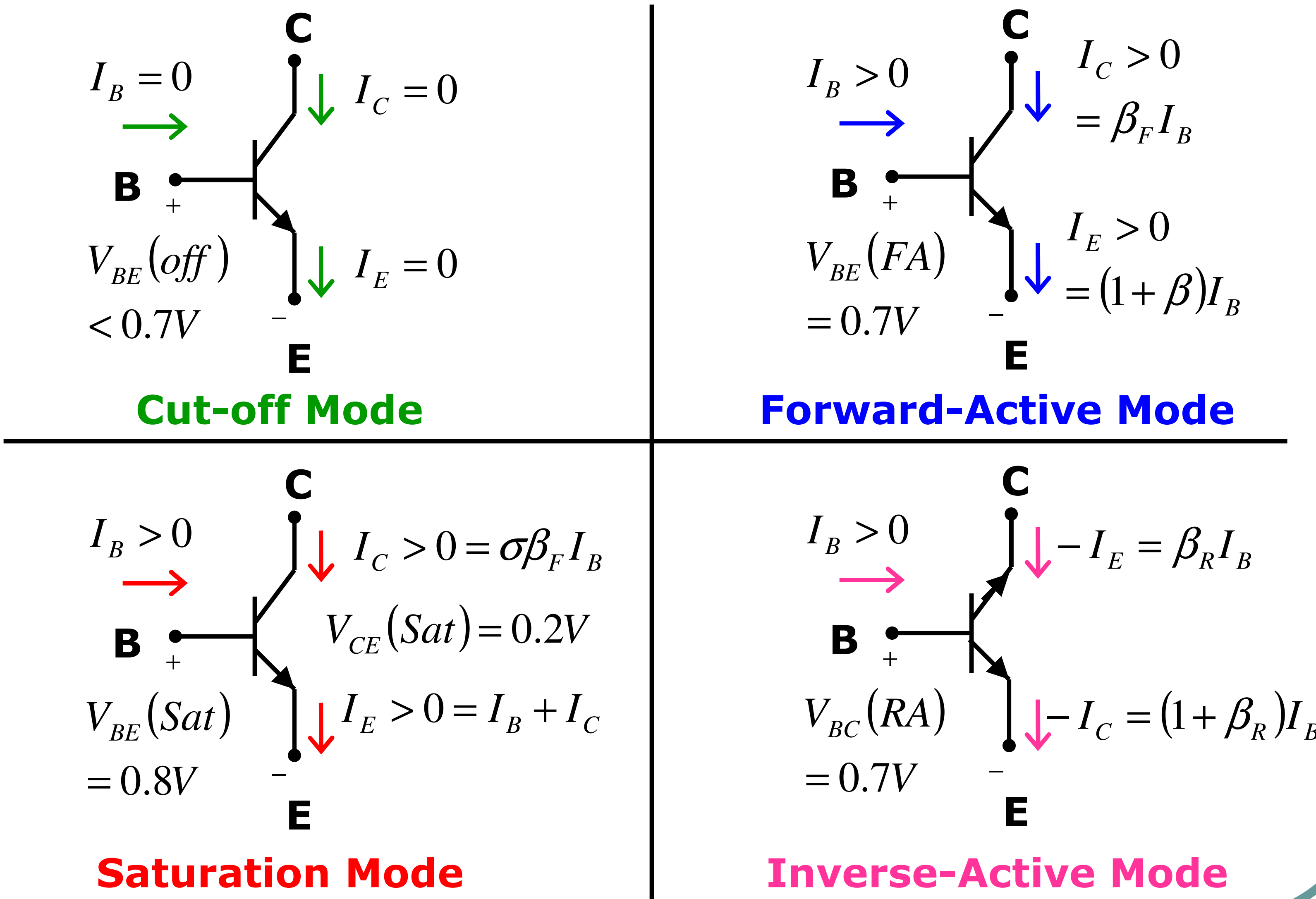


Terminal Currents and Voltages

- **Example**

Determine I_C , I_B, and σ for the BJT shown in the following circuit, assuming β=65

- **Solution**

Assume FA, V_{BE}=0.7V and then calculate V_{CE}. If V_{CE}<=0.2 then the BJT operates in saturation mode

$$V_{CE} << 0.2$$

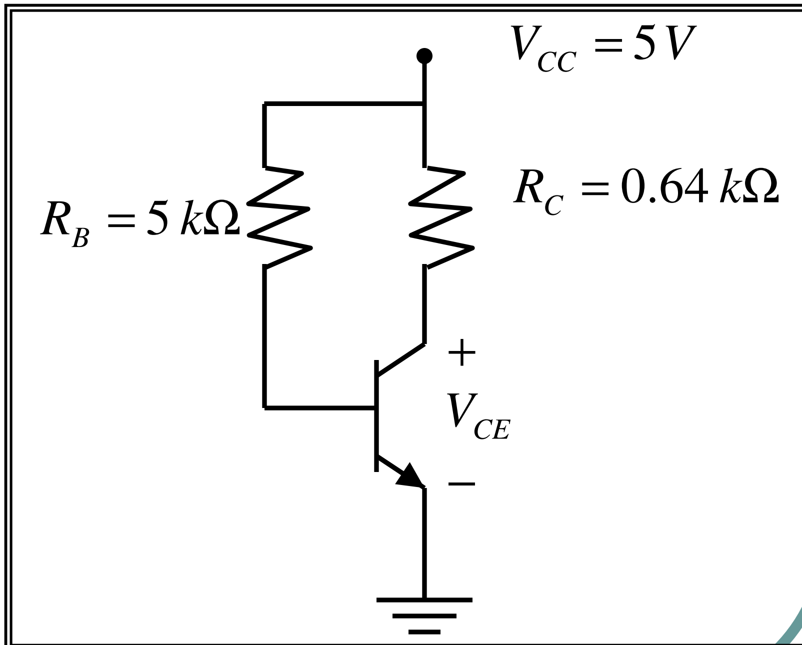
The BJT operates in saturation mode i.e.

$$V_{CE}(sat) = 0.2V \qquad V_{BE}(sat) = 0.8V$$

$$I_B = \frac{V_{CC} - V_{BE}(sat)}{R_B} = 0.84mA$$

$$I_C = \frac{V_{CC} - V_{CE}(sat)}{R_C} = 7.5mA$$

$$\sigma = \frac{I_C}{\beta_F I_B} = 0.137$$



- **Example**

Determine the terminal voltages of the transistors shown in the following circuit, assuming Q_1 operates in saturation mode while Q_2 and Q_3 operate in forward-active mode

- **Solution**

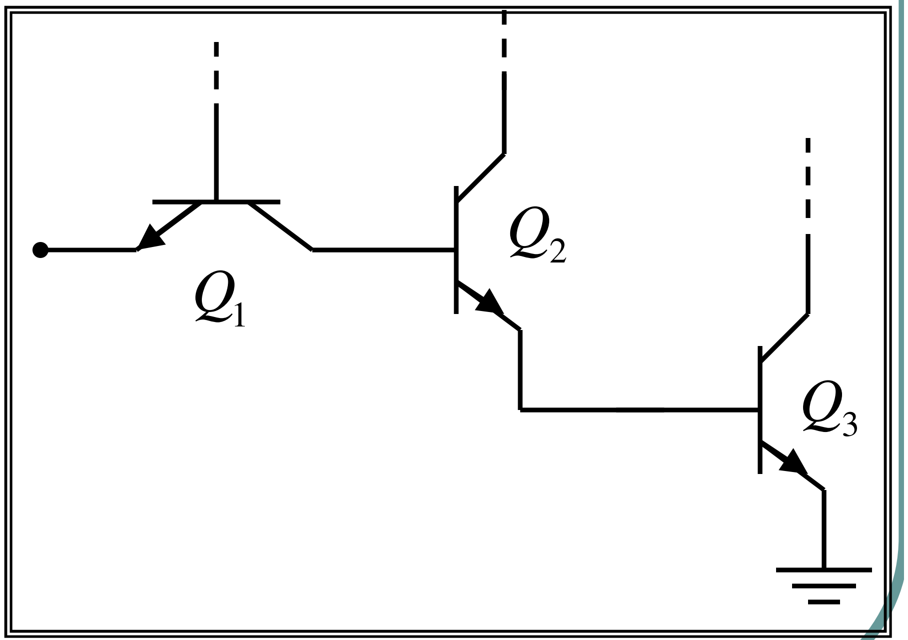
$$V_{E3} = 0.0V$$

$$V_{B3} = 0.7V$$

$$V_{B2} = 0.7 + 0.7 = 1.4V$$

$$V_{B1} = 0.6 + 1.4 = 2V$$

$$V_{E1} = -0.2 + 1.4 = 1.2V$$



Terminal Currents and Voltages With Known States

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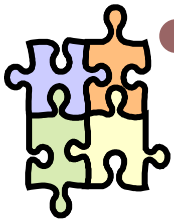
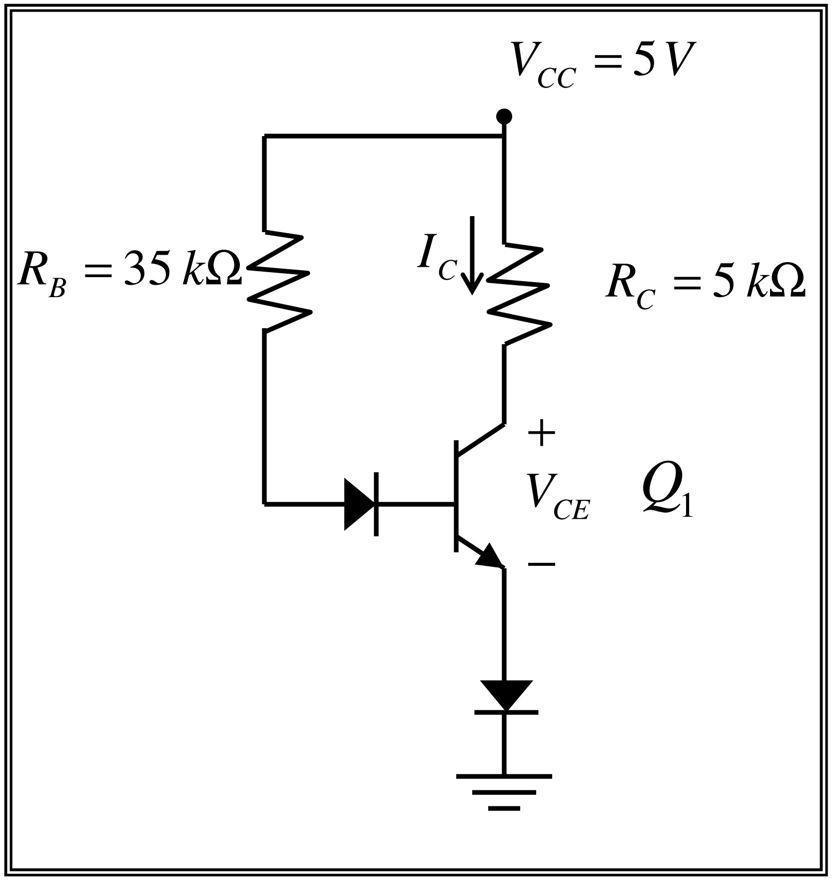


- Example

Determine the dissipated power P_{CC} in the following circuit, given that the BJT operates in saturation mode



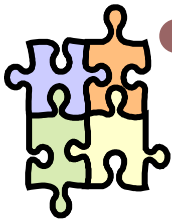
- Solution

$$P_{CC} = V_{CC} \times \left(\frac{V_{CC} - V_{CE}(sat) - V_D(ON)}{R_C} + \frac{V_{CC} - V_{BE}(sat) - 2V_D(ON)}{R_B} \right)$$

$$P_{CC} = 5 \times (0.82 + 0.08) = 4.5 mW$$

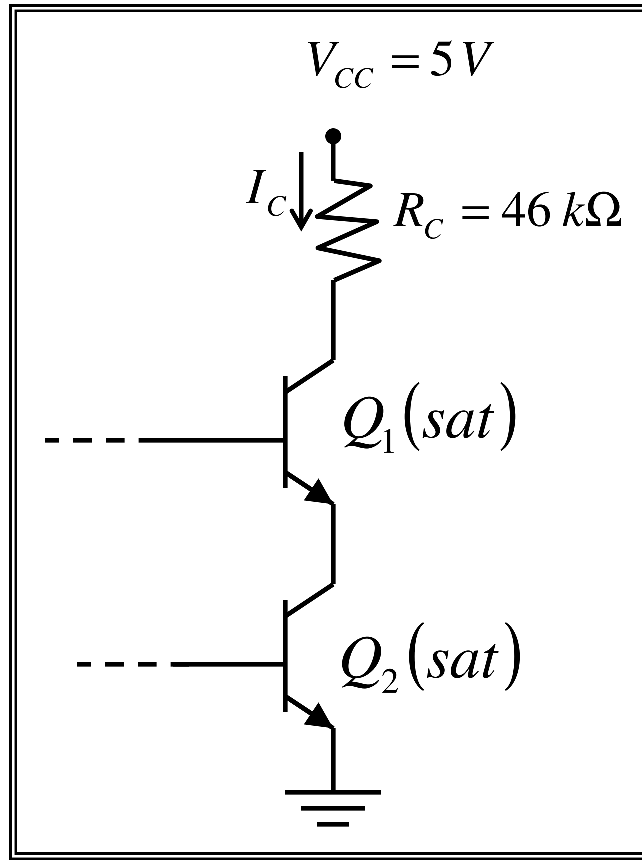
I_{CC} (OL)

Terminal Currents and Voltages With Known States



- Example

Determine the current I_C in the following circuit.



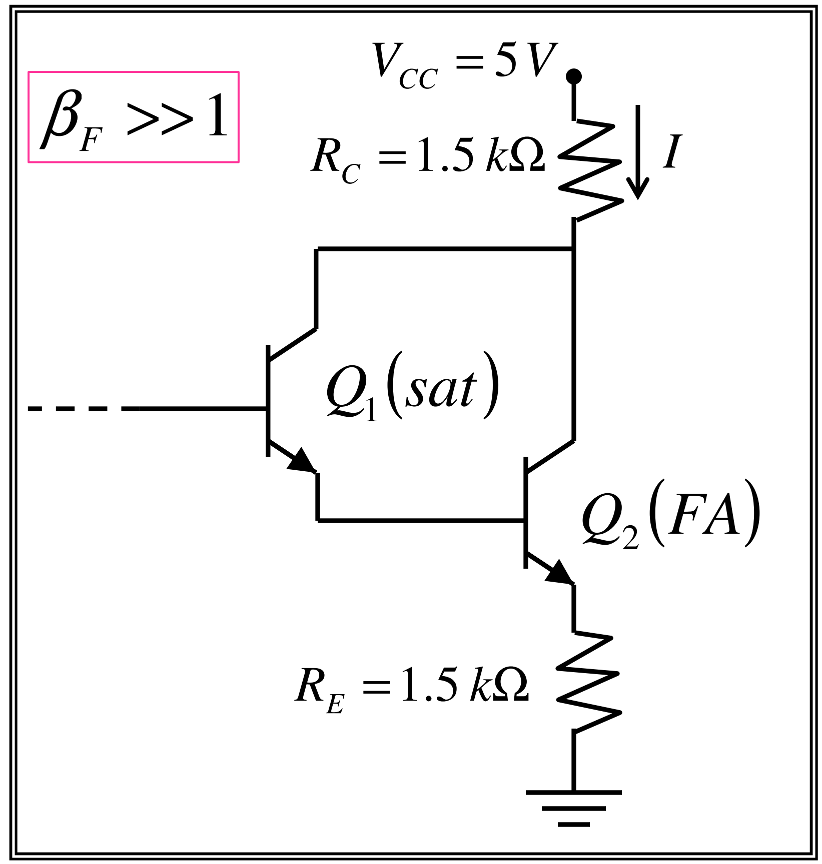
- Solution

$$I_C = \frac{V_{CC} - 2V_{CE}(sat)}{R_C} = 0.1mA$$

Terminal Currents and Voltages With Known States

- Example

Determine the current I in the following circuit neglecting the base currents.



- Solution

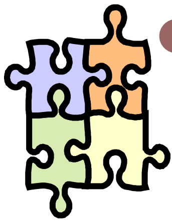
$I_{C2} = I_{E2}$ Since $\beta_F >> 1$

$I_{C2} = I$ Since $I_{B2} <<$ i.e $I_{E1} <<$ & $I_{C1} <<$

$$I = \frac{V_{CC} - V_{CE1}(sat) - V_{BE1}(FA)}{R_C + R_E}$$

$$I = 1.367\,mA$$

Terminal Currents and Voltages With Known States



- Example

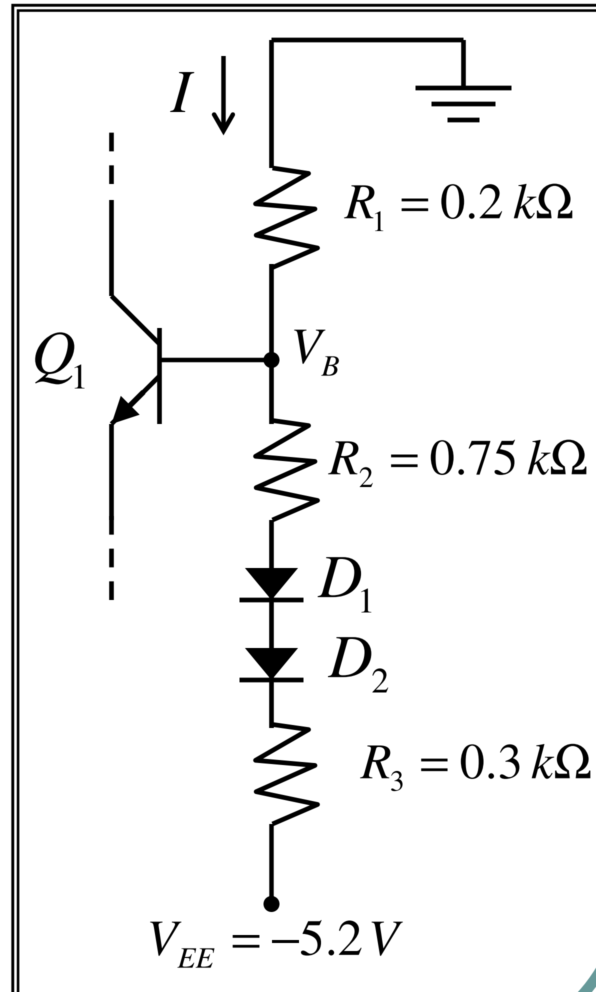
Determine the voltage V_B and the current I indicated the circuit shown below assuming the base current of Q_1 is negligible.

- Solution

$$I = \frac{0 - V_{EE} - 2V_D(ON)}{R_1 + R_2 + R_3}$$

$$= \frac{5.2 - 1.4}{0.2 + 0.75 + 0.3} = 3.04mA$$

$$V_B = 0 - IR_1 = -3.04 \times 0.2 = -0.608V$$



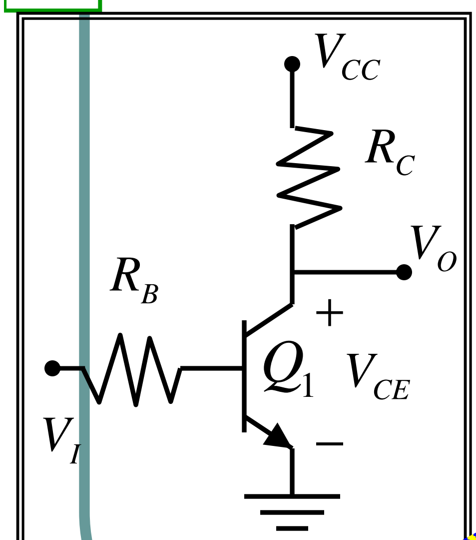
BJT Inverter (Basic RTL Inverter)

- Voltage-Transfer Characteristics

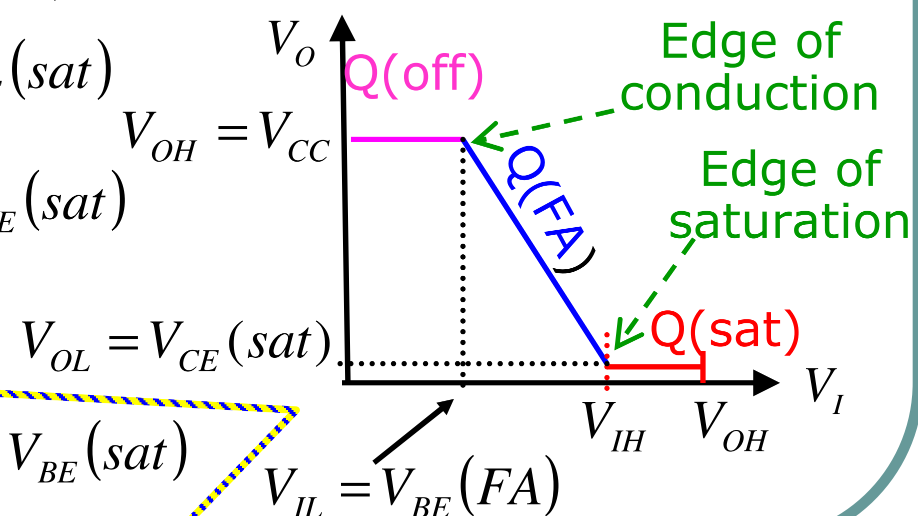
For $V_I - GND < V_{BE}(FA)$ ⇒ $I_B=0, I_C=0, V_O=V_{CC}=V_{OH}$

For $V_I - GND \geq V_{BE}(FA)$ ⇒ $I_B=(V_I-V_{BE}(FA))/R_B, I_C=\beta_F I_B, V_O=V_{CC}-I_C R_C$

For $V_I - GND \geq V_{IH}$ ⇒ $I_B=(V_I-V_{BE}(sat))/R_B$, $I_C=(V_{CC}-V_{CE}(sat))/R_C$, $V_O=V_{CE}(sat)=V_{OL}$

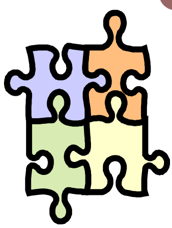


$$V_{IH} = I_B(sat)R_B + V_{BE}(sat)$$
$$= I_B(EOS)R_B + V_{BE}(sat)$$
$$= \frac{I_C(EOS)}{\beta_F} R_B + V_{BE}(sat)$$



$$V_{IH} = \frac{V_{CC} - V_{CE}(sat)}{\beta_F R_C} R_B + V_{BE}(sat)$$

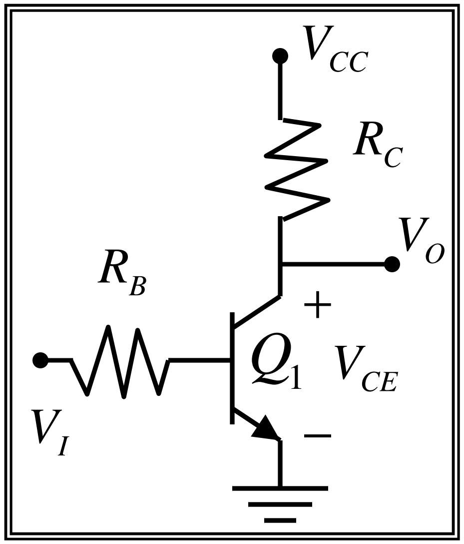
BJT Inverter (Basic RTL Inverter)



- Example

Assume V_{CC}= 5 V, R_C= 1kΩ , R_B= 10 kΩ, β_F=60;

Determine the <u>VTC</u> parameters and the low and high noise margins



- Solution

V_{IL}= 0.7 V, V_{IH}= 1.6 V,

V_{OL}= 0.2 V, V_{OH}= 5 V,

$$N_{ML} = V_{IL} - V_{OL} = 0.5V$$

Small value

$$N_{MH} = V_{OH} - V_{IH} = 3.4V$$

- HW #4:Solve Problems: 4.1 (a)&(d), 4.3, 4.11, 4.12, 4.13, 4.21

Skip sections 4.3-4.6